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| *Title:* | **RCE1: Results of subtests B5, B6 and B7** | | |
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# Abstract

This document reports the experimental results for subtests B5, B6 and B7 of HEVC Range Extensions core experiment 1, as described in document JCTVC-O1121. These tests combine the throughput improvement techniques in subtests A1, A2 and A3 with the alignment of ivlCurrRange to 256 before bypass coding to enable subsequent coding of bypass coded bins as raw.

It is reported that methods B5 and B6 show small degradation in BD-rate performance compared to the anchor under AHG18 and AHG5 test conditions (up to 0.2% and up to 0.1%, respectively). It is asserted that methods B5 and B6 reduce the number of context-coded bins for a 4×4 subblock by 18% and 50%, respectively, in the worst-case. It is also asserted that in the worst-case, methods B5 and B6 enable coding of 50% bypass bins as raw. It is reported that under AHG18 test conditions and internal bit-depth of 16 bits, on average, methods B5 and B6 reduce the number of context-coded bins for a 4×4 subblock by 20% and 55%, respectively. It is also reported that under AHG18 test conditions and internal bit-depth of 16 bits, on average, the percentage of bypass bins coded as raw for methods B5 and B6 is around 80%.

# Introduction

In JCTVC-P0073, results for subtest A of HEVC Range Extensions core experiment 1 (JCTVC-O1121) are reported. Subtests A1, A2 and A3 switch from context-coded bins to bypass bins at different positions in transform coefficient coding. Converting context-coded bins to bypass results in improved throughput. However, bypass coding still uses the CABAC engine. JCTVC-M0178, JCTVC-N0190, and JCTVC-O0046 proposed alignment techniques before bypass coding to enable subsequent coding of bypass coded bins as raw. In subtests B5, B6 and B7 alignment of ivlCurrRange to 256 is tested in combination with the switch from context-coded bins to bypass coding proposed in subtests A1, A2 and A3.

## Subtest B5

This represents a combination of subtest A1 with the alignment of ivlCurrRange to 256. Whenever, the Golomb Rice parameter at the end of the previous 4×4 subblock is greater than or equal to a threshold (4), the coding of *coeff\_abs\_level\_greater1* and *coeff\_abs\_level\_greater2* flags is skipped for the current 4×4 subblock. Furthermore, for the current 4×4 subblock, ivlCurrRange is aligned to 256 before the coding pass for *coeff\_sign\_flag*.

The *coeff\_abs\_level\_remaining* syntax element is adjusted to account for the fact that *coeff\_abs\_level\_greater1* and *coeff\_abs\_level\_greater2* flags are not coded.

## Subtest B6

This represents a combination of subtest A2 with the alignment of ivlCurrRange to 256. Whenever, the Golomb Rice parameter at the end of the previous 4×4 subblock is greater than or equal to a threshold (4), the coding of *coded\_sub\_block\_flag*, *significance\_coeff\_flag*, *coeff\_abs\_level\_greater1* and *coeff\_abs\_level\_greater2* flags is skipped for the current 4×4 subblock. In this case the coding pass for *coeff\_sign\_flag* comes after the coding pass for the *coeff\_abs\_level\_remaining* syntax element. Furthermore, for the current 4×4 subblock, ivlCurrRange is aligned to 256 before the coding pass for *coeff\_abs\_level\_remaining*.

The *coeff\_abs\_level\_remaining* syntax element is adjusted to account for the fact that *significance\_coeff\_flag*, *coeff\_abs\_level\_greater1* and *coeff\_abs\_level\_greater2* flags are not coded.

## Subtest B7

This represents a combination of subtest A3 with the alignment of ivlCurrRange to 256. Whenever, the Golomb Rice parameter at the end of the previous transform block is greater than or equal to a threshold (4), the coding of *coded\_sub\_block\_flag*, *significance\_coeff\_flag*, *coeff\_abs\_level\_greater1* and *coeff\_abs\_level\_greater2* flags is skipped for the current transform block. The last significant coefficient position is coded in bypass mode as (blockSizeX – LastSignificantCoeffX) and (blockSizeY – LastSignificantCoeffY). Furthermore, for the current transform block, ivlCurrRange is aligned to 256 before the coding of the last significant coefficient position.

In this case the coding pass for *coeff\_sign\_flag* comes after the coding pass for the *coeff\_abs\_level\_remaining* syntax element. The *coeff\_abs\_level\_remaining* syntax element is adjusted to account for the fact that *significance\_coeff\_flag*, *coeff\_abs\_level\_greater1* and *coeff\_abs\_level\_greater2* flags are not coded.

# Simulation results

The proposal is implemented on top of HM12.1\_Rext5.1. Simulations are performed under AHG18, AHG5 and AHG8 (lossless) test conditions. The performance is compared to the anchor in terms of BD-rate savings.

## AHG18 results



Table 1: BD-rate results for subtest B5 for AHG18 test conditions (threshold 4)



Table 2: BD-rate results for subtest B6 for AHG18 test conditions (threshold 4)



Table 3: BD-rate results for subtest B7 for AHG18 test conditions (threshold 4)

## AHG5 results



Table 4: BD-rate results for subtest B5 for AHG5 test conditions (threshold 4)



Table 5: BD-rate results for subtest B6 for AHG5 test conditions (threshold 4)



Table 6: BD-rate results for subtest B7 for AHG5 test conditions (threshold 4)

## AHG8 (lossless) results



Table 7: BD-rate results for subtest B5 for AHG8 (lossless) test conditions (threshold 4)



Table 8: BD-rate results for subtest B6 for AHG8 (lossless) test conditions (threshold 4)



Table 9: BD-rate results for subtest B7 for AHG8 (lossless) test conditions (threshold 4)

# Throughput

## Bin counts per component per sample



Table 10: Average bin count for subtest B5 under AHG18 test conditions



Table 11: Average bin count for subtest B6 under AHG18 test conditions



Table 12: Average bin count for subtest B7 under AHG18 test conditions

## Throughput Analysis

Main advantage of the proposed methods is that they reduce the number of context-coded bins and also enable coding of bypass bins as raw based on a single criterion. Even though both context-coded and bypass bins use CABAC engine, bypass mode is much simpler as there is no state update. On some software architectures, division instruction can be used to decode multiple bypass bins. Although for different architectures may have varying advantages for decoding bypass bins over context-coded bins, it is reasonable to say that the throughput bypass bins may be 5X or higher compared to the context-coded bins. The throughput can be further enhanced by enabling the decoding of the bypass bins as raw instead of going through the CABAC engine.

The previous subsection has provided average bin counts for the proposals. Here we present the analysis of the worst case. Since the criterion for switching to bypass mode and for bypass alignment depends on the Golomb Rice parameter at the end of the last 4×4 subblock, the worst case complexity upper bound is calculated over 2 consecutive 4×4 subblocks. If the Golomb Rice parameter at the end of the first 4×4 subblock is less than 4, the number of total bins is much lower than the worst case. So we will concentrate on the case when the first block achieves the worst case complexity. In this case, the complexities for subtests B5 and B6 are as specified in Tables 13 and 14. Since subtest B7 has much worse BD-rate performance, we have not included it in the analysis. It should be noted that the worst-case upper bound is not tight. For example, if the 2nd 4×4 subblock has the maximum possible bypass bins, the 3rd subblock will also satisfy the criterion for switching to bypass mode and for bypass alignment. Thus, the worst case averaged over 3 4×4 subblocks will be better than the worst case upper bound shown in Tables 13 and 14.

For context-coded bins, in the worst case, 16 significance flags, 8 *coeff\_abs\_level\_greater1* flags and 1 *coeff\_abs\_level\_greater2* flag are possible. For the bypass bins, it is assumed that GolomRiceGroupAdaptation is enabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Base | 1st 4×4 subblock | 2nd 4×4 subblock | Average |
| Total number of context bins | 16+8+1 = 25 | 25 | 16 | 20.5 |
| Total number of bypass bins with CABAC | (1+46) + (1+39)\*15 = 647 | 647 | 0 | 323.5 |
| Total number of bypass bins (raw) | 0 | 0 | 647 | 323.5 |

Table 13: Analysis of worst-case bin count for subtest B5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Base | 1st 4×4 subblock | 2nd 4×4 subblock | average |
| Total number of context bins | 16+8+1 = 26 | 25 | 0 | 12.5 |
| Total number of bypass bins with CABAC | (1+46) + (1+39)\*15 = 647 | 647 | 0 | 323.5 |
| Total number of bypass bins (raw) | 0 | 0 | 647 | 323.5 |

Table 14: Analysis of worst-case bin count for subtest B6

# Conclusions

Combinations of subtests A1, A2, and A3 with the alignment of ivlCurrRange to 256 before bypass coding are tested in subtests B5, B6, and B7, respectively. The alignment is performed when the Golomb Rice parameter at the end of the last 4×4 subblock is greater than or equal to a threshold (4). This is also the criterion for moving from context-coded bins to bypass coding in subtests A1, A2, and A3.

Method B5 has small BD-rate loss compared to the anchor for AHG18 test conditions (up to 0.2%) and AHG5 test conditions (up to 0.1%). It has a slightly larger loss (in the range of 0.0% to 0.5%) for mandatory sequence classes under AHG8 lossless test conditions. It reduces the number of context-coded bins in the worst-case for a 4×4 subblock by 18%. Furthermore, in the worst-case, 50% of the bypass bins are coded as raw. On average, for internal bit-depth of 16 bits, the reduction in context-coded bins is 20% and the percentage of bypass bins coded as raw is 80%.

Method B6 has small BD-rate loss compared to the anchor for AHG18 test conditions (up to 0.2%) and AHG5 test conditions (up to 0.1%). However, under AHG8 lossless test conditions, large losses are observed for screen content sequences. Method B6 reduces the number of context-coded bins in the worst-case for a 4×4 subblock by 50%. Furthermore, in the worst-case, 50% of the bypass bins are coded as raw. On average, for internal bit-depth of 16 bits, the reduction in context-coded bins is 55% and the percentage of bypass bins coded as raw is 82%.

# Patent rights declaration(s)

**Qualcomm Inc. may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**